JOURNAL of FORENSIC ODONTO-STOMATOLOGY
VOLUME 35 Number 1 July 2017

SECTION ANTHROPOLOGY

Palatal Rugae Morphology In An Adult Mediterranean Population

Maria Saadeh[1,2], Joseph G. Ghafari[1,2,3], Ramzi V. Haddad[2], Fouad Ayoub[4]

[1]*Department of Orthodontics, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon*
[2]*Division of Orthodontics and Dentofacial Orthopedics, American University of Beirut Medical Center, Beirut, Lebanon*
[3]*Department of Orthodontics, University of Pennsylvania, Philadelphia, USA*
[4]*Department of Forensic Odontology, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon*

Corresponding author: ***prof.ayoub@intracom.net.lb***

The authors declare that they have no conflict of interest.

ABSTRACT

Background: The use of the palatal rugae in forensic odontology is based on their unique and individual characteristics. Few studies have assessed the palatal rugae in Mediterranean populations and none in the Lebanese population. Objective: Assess the shape and other morphological features of the palatal rugae in a Lebanese adult population, and compare them with reported similar features in other populations. Materials and methods: Rugae characteristics were assessed on the maxillary dental casts of 217 non-growing subjects (95 males, 122 females, age 25.5 ± 7.6 years) according to guidelines established by Thomas and Kotze (1983) and Lysell (1955). The overall number of rugae and numbers of primary rugae (>5mm in length), secondary rugae (3-5mm) and fragmentary rugae (2-3mm) on either side were recorded. Rugae were classified according to shape, direction and presence of unification. Z-tests were used to compare the proportions between right and left sides and between genders. The mean numbers of rugae in each category were compared with independent samples t-tests between males and females; paired samples t-tests were employed to compare mean numbers of rugae in each category between right and left sides. The data were compared with published reports on other Mediterranean cohorts. Results: The average number of rugae was 7.7 per individual, 3.81 on the right and 3.89 on the left. Curved, wavy and straight rugae patterns were equally common (one third each). The spatial direction of most rugae (49.3%) was backward. Circular, non-specific and convergent rugae were rare (<2% each). Rugae numbers (total, primary, secondary, fragmentary) were symmetrical but shape, direction and the occurrence of convergence were asymmetrical ($p < 0.05$). None of the examined characteristics showed gender dimorphism. Tabulated comparisons disclosed the equality of rugae patterns as major differences with findings from other Mediterranean studies. Conclusions: The palatal rugae in the Lebanese population display shape distinct from other reported Mediterranean and non-Caucasian populations. Studies in large samples and primary comparisons with other Mediterranean populations are warranted.

KEYWORDS: Palatal rugae, morphology, Mediterranean, forensic odontology, human identification

JFOS. July 2017, Vol.35, No.1 Pag 21-32
ISSN :2219-6749

INTRODUCTION

The palatal rugae may be used in ascertaining an individual's identity when conventional forensic methods (fingerprints, DNA, dental records) prove inadequate for post-mortem identification. These structures comprise a series of transverse folds of mucosa located in the anterior region of the palate on either side of the median palatal raphe.[1] Protected by the teeth, lips, tongue and buccal pads of fat, the palatal rugae have been found to be highly resistant to the physical conditions accompanied by natural and artificial disasters (e.g. fires, chemicals and high-impact trauma) and have been shown to resist decomposition for up to seven days after death.[1-2]

When present, a ante-mortem record of the palatal rugae would enable accurate post-mortem identification in up 90 - 100% of cases.[3] Accordingly, researchers have increasingly attempted to assess palatal rugae morphology in various populations, focusing on specific features such as symmetry and gender differences, to better understand their potential in individual, gender and population identification. Classification systems categorize the rugae on such characteristics as length, shape, direction and the presence of unification or divergence.[4,5,6] The classifications of Lysell[7] and Thomas and Kotze[8] have been the most widely used in research of the palatal rugae, allowing comparative panels for ethnic specificity and racial disparities.[9-12] Regarding gender, research outcome is split between support[13-16] and absence[17-19] of gender dimorphism.

The evaluation of palatal rugae morphology in adult Mediterranean populations has been limited[12,16] and lacking in Lebanon, where the population is qualified as Caucasian. The aim of this study is to assess the morphology of the palatal rugae in a Mediterranean Lebanese adult population and to explore the presence of bilateral symmetry and gender dimorphism.

MATERIAL AND METHODS

This is a cross-sectional study on the pre-treatment orthodontic records of 217 subjects (95 males, 122 females, mean age 25.5 ± 7.6 years) who were selected from the database of patients at the American University of Beirut Medical Center. Included were maxillary dental casts deemed of high quality, taken of non-growing subjects (age > 16 years for females and >18 years for males) who had a complete set of fully erupted permanent teeth (excluding third molars), no posterior cross-bite and crowding < 2mm. Excluded were subjects with systemic disease, craniofacial anomalies, history of orthodontic treatment and/or surgical treatment involving the head and neck were excluded. The study was approved by the Institutional Review Board.

Maxillary dental casts were de-identified by research support personnel not directly involved in the investigation. The principal investigator performed all research procedures, starting with direct visual inspection of the palatal area on each maxillary dental cast, assessing and drawing with a pencil the palatal rugae, then classifying them according to the systems of Lysell[7] and Thomas and Kotze,[8] as described by Kapali et al.[21] (**Table 1, Fig1**).

The length stratification was performed directly on the dental casts; the actual lengths of the rugae were then compared for correspondence with the digital record derived from the scanned models. The visual categorization on length (primary, secondary, fragmentary) was compared with the digital length measures of corresponding rugae on 50 casts using the kappa statistics, which yielded a high correspondence coefficient. Thus, the frequencies of length categories defined on

Table 1. Classification criteria of palatal rugae

Criteria	Description
Length	- primary rugae (>5mm in length); - secondary rugae (3-5mm in length) - fragmentary rugae (2-3mm in length). *Rugae less than 2mm in length were discarded.*
Shape (Fig. 1A)	- curved: simple crescent shape that curves gently in the middle of the ruga - wavy: basic serpentine shape, or presence of slight curves at ruga origin or termination - straight: runs in straight line from origin to termination) - circle: forming a continuous definite ring) or non-specific (not conforming to any of the described shapes).
Angle formed between ruga and a line perpendicular to the median palatal raphe (MPR)- (Fig. 1B)	- forward-directed (positive angle formed with MPR perpendicular); - straight (parallel to MPR perpendicular) - backward-directed (negative angle formed with MPR perpendicular).
Presence of unification (Fig. 1C)	- absent (ruga has one origin and one termination) - diverging (immediate branching of the ruga from a common origin at the medial aspect) - converging (different origins that join in one termination at the lateral aspect).

the dental casts were used in the statistical analyses.

Outcome measures: Descriptive statistics of the palatal rugae for each category of length, shape, direction and unification were generated. To provide for the possibility of comparisons with prior studies, we included two sets of outcome measurements:
1- within subjects: incidence of at least one palatal ruga in each category of classification within subjects, as well as the mean numbers of rugae for each classification category, with their respective standard deviations (SDs).
2- across subjects: the proportion relative to the total number of assessed rugae of the overall number of assessed rugae belonging to each morphological category (length, shape, direction and presence of unification).

Statistics: Z-tests for the differences between proportions were used to evaluate the differences in prevalence between right and left sides and between male and female subjects. The mean numbers of rugae in each classification category were compared between male and female subjects with independent t-tests; right/left differences were compared with paired samples t-tests.
Rugae measurements and characterizations were repeated by another investigator (R.H.) on 50 randomly selected casts. The repetitions included the recognition of shape as well as identification of landmarks that served to measure rugae length. Similarly, rugae in 50 randomly selected models were reclassified by the principal investigator (M.S.) at least 14 days after initial assessment. The repeated measures were evaluated with the two-way mixed effects intra-class correlations for absolute agreement on single measures to calculate both inter and intra-examiner errors. The data were computed through the Statistical Package for Social Sciences (IBM SPSS®, version 20.0, Armonk, NY)

and Stata Statistical Software (version 11.1, College Station, TX). Statistical significance was set at 0.05.

RESULTS

Reliability of repeated measurements within and between operators was high. The intraclass correlation coefficients in measuring the rugae length varied from 0.897 to 0.996 for the intra-rater and from 0.865 to 0.991 for the inter-rater reliability. When recognizing the different categories of shapes, direction and unification, the intra-rater reliability ranged between 0.892 and 0.968 and between 0.875 and 0.977 for the inter-rater reliability.

At both the individual and total sample assessment levels, the palatal rugae generally exhibited lateral symmetry with respect to length category, as the mean numbers of primary, secondary and fragmentary rugae were similar on both sides (**Tables 2, 3**). Symmetry was also noted for the presence and mean number of divergent rugae and rugae without unification. On the other hand, rugae shape, direction, and convergent rugae were asymmetrical.

At the individual level, the mean number of rugae per individual was 3.81 ± 0.83 on the right and 3.89 ± 0.86 on the left. The majority of the rugae were primary (100% incidence), 3.23 ± 0.52 and 3.29 ± 0.56 per individual on the right and left sides, respectively **(Table 2)**.

Table 2. Frequency of number of palatal rugae (1 to 7) as described by Thomas and Kotze (n = 217)

	Incidence n (%)		No. per individual Mean (SD)		Total no. rugae n (%)		
	Right	Left	Right	Left	Right	Left	Total
Number							
First	217 (100)	217 (100)			217 (26.3)	217 (25.7)	434 (26)
Second	217 (100)	217 (100)			217 (26.3)	217 (25.7)	434 (26)
Third	217 (100)	217 (100)			217 (26.3)	217 (25.7)	434 (26)
Fourth	127 (58.5)	133 (61.2)	3.81	3.89	127 (15.4)	133 (15.8)	260 (15.6)
Fifth	40 (18.4)	48 (22.1)	(0.83)	(0.86)	40 (4.8)	48 (5.7)	88 (5.2)
Sixth	7 (3.2)	10 (4.6)			7 (0.8)	10 (1.2)	17 (1.0)
Seventh	1 (0.5)	2 (0.9)			1 (0.1)	2 (0.2)	3 (0.2)
Total	217 (100)	217 (100)			826 (100)	844 (100)	1670 (100)

The most commonly occurring shapes were curved, wavy and straight. On average, each subject had around one curved, wavy and straight ruga on each side of the palate (mean values ranging between 1.13 ± 0.95 and 1.4 ±1.06) **(Table 3)**. The incidence and mean numbers of wavy, circular and nonspecific rugae were similar on both sides of the palate. However, the mean number of curved rugae was greater on the left ($p = 0.001$) and the mean number of straight rugae was conversely larger on the right ($p = 0.04$).

With respect to rugae direction (**Table 3**), the right side of the palate included a larger mean number of forward-directing (0.93 ± 1.05 compared to 0.45 ± 0.88 on the left, $p < 0.001$) and straight rugae (1.44 ± 1.09 compared to 1.08 ± 1.14 on the left, $p < 0.001$), whereas the mean number of backward-directing rugae was greater on the left side of the palate (2.35 ± 1.5 compared to 1.44 ± 1.29 on the right, $p < 0.001$). A similar trend was noted for the incidence of palatal rugae direction ($p < 0.001$, 0.001 and 0.003, in forward, straight and backward categories, respectively).

The incidence of rugae without unification was almost universal, 99.5% and 100% on the right and left sides, respectively. Convergent forms were the least occurring, and also asymmetrical in number and incidence (**Table 3**).

When the total of 1670 rugae across subjects was assessed, all subjects were found to have at least 3 rugae on either side of the palate (incidence = 100 %). The incidence of additional rugae gradually decreased with increasing numbers of rugae, less than 5% of the subjects possessing more than 5 rugae on either side of the palate. Fewer than one third of the subjects possessed secondary rugae (27.2% incidence on the right and 29.5% incidence on the left) and around one fifth possessed fragmentary rugae (23.5% on the right and 17.1% on the left) (**Table 2**).

The most occurring shapes were nearly equally the curved (33.1%), wavy (32.6%) and straight (33.7%) rugae, each of them representing around one third of the total number of assessed rugae (**Table 3**). The circular and nonspecific rugae combined formed less than 1% of all counted rugae. The frequency rates per side were also similar.

Backward-oriented rugae were the most common (nearly 50%), equal to the rates of forward-leaning (17.9%) and straight (32.8%) rugae combined. While the majority of the latter were more frequent on the right side, the backward-directed were more common on the left side ($p<0.001$).

The incidence of rugae without unification was highest (88.8%), equal on right and left sides. Rugae that were either divergent or convergent formed 11.2% of all assessed rugae, convergent rugae reflecting an especially rare occurrence (1.8% of all rugae) (**Table 3**).

None of the assessed morphological rugae characteristics (mean number, various shapes, direction, and unification) exhibited gender dimorphism (p = 0.128 – 0.850; **Table 4**). When assessed for symmetry, the same patterns described above for within and across subjects were observed. In both genders, asymmetry was noted among curved, forward/straight/backward directed, and convergent rugae (Table **5,6**).

DISCUSSION

This investigation is the first to describe palatal rugae morphology in the Lebanese population, typically a Caucasian population, and one of very few describing the rugae in the Mediterranean basin.[12,16]

Our data complement the literature defining palatal rugae in different ethnic and racial backgrounds. Comparisons with other studies are limited by our inclusion of only English publications, and the prevalence of studies from Asian populations. Nevertheless, the methods used in these studies originated from classifications of subjects of Caucasian origins, underlying the fact that rugae have universal characteristics.[7]

The mean number of palatal rugae per individual recorded in our sample is comparable to averages reported in Caucasian, European and Middle Eastern populations (Swedes[7], Central Europeans[7], Australian[21], Bosnian[16], Jordan[27], Saudi Arabian[22]), lower than those from Asian and African countries (India, Sudan[23]; **Table 7**). An arbitrary cut-off between the higher and lower frequencies may be set at a mean of 9 total rugae per individual, only as a guideline to be tested in future research.[4,24,25]

In the majority of the various studies, regardless of geographic origin, one or two dominant palatal rugae shapes appear

Table 3. Differences in palatal rugae characteristics between right and left sides, according to Thomas and Kotze classification (n = 217)

	Incidence			Number per individual			Total no. rugae			
	Right n (%)	Left n (%)	p^a	Right Mean (SD)	Left Mean (SD)	p^b	Total n (%)	Right n (%)	Left n (%)	p^a
Length										
Primary	217 (100)	217 (100)	-	3.23 (0.52)	3.29 (0.56)	0.19	1414 (84.7)	700 (84.7)	714 (84.6)	0.955
Secondary	59 (27.2)	64 (29.5)	0.595	0.31 (0.54)	0.38 (0.66)	0.214	149 (8.9)	67 (8.1)	82 (9.7)	0.251
Fragmentary	51 (23.5)	37 (17.1)	0.097	0.27 (0.52)	0.22 (0.53)	0.334	107 (6.4)	59 (7.2)	48 (5.7)	0.212
Shape										
Curved	157 (72.4)	178 (82)	0.017*	1.13 (0.95)	1.41 (0.99)	0.001**	552 (33.1)	245 (29.7)	307 (36.4)	0.004**
Wavy	159 (73.3)	171 (78.8)	0.180	1.26 (1.01)	1.25 (0.9)	0.917	544 (32.6)	273 (33.0)	271 (32.1)	0.695
Straight	170 (78.3)	160 (73.7)	0.262	1.40 (1.06)	1.20 (1.02)	0.040*	563 (33.7)	303 (36.7)	260 (30.8)	0.011*
Cirvular	5 (2.3)	5 (2.3)	1	0.02 (0.15)	0.02 (0.15)	1.000	10 (0.6)	5 (0.6)	5 (0.6)	1.000
Nonspecific	0 (0)	1 (0.5)	0.297	0 (0)	0 (0.07)	0.318	1 (0.1)	0 (0)	1 (0.1)	0.363
Direction										
Forward	120 (55.3)	63 (29)	<0.001**	0.93 (1.05)	0.45 (0.88)	<0.001**	299 (17.9)	201 (24.3)	98 (11.6)	<0.001**
Straight	168 (77.4)	132 (60.8)	0.001**	1.44 (1.09)	1.08 (1.14)	<0.001**	548 (32.8)	313 (37.9)	235 (27.9)	<0.001**
Backward	160 (73.7)	185 (85.3)	0.003**	1.44 (1.29)	2.35 (1.5)	<0.001**	823 (49.3)	312 (37.8)	511 (60.5)	<0.001**
Unification										
Absent	216 (99.5)	217 (100)	0.297	3.39 (1.04)	3.45 (1.09)	0.487	1483 (88.8)	735 (89.0)	748 (88.6)	0.796
Divergent	81 (37.3)	65 (30)	0.108	0.40 (0.54)	0.33 (0.54)	0.124	157 (9.4)	86 (10.4)	71 (8.4)	0.161
Convergent	5 (2.3)	24 (11.1)	0.001**	0.02 (0.15)	0.12 (0.33)	<0.001**	30 (1.8)	5 (0.6)	25 (3)	<0.001**

[a]Z- test; [b]paired t test; *significant, p<0.05; **significant, p<0.01.

Table 4. Differences in palatal rugae characteristics between males and females, according to Thomas and Kotze classification (n = 217)

	Incidence			Number per individual		
	Males (n = 95)	Females (n = 122)		Males (n = 95)	Females (n = 122)	
	n (%)	n (%)	p^a	Mean (SD)	Mean (SD)	p^b
Length						
Primary	95 (100.0)	122 (100.0)	-	6.57 (0.87)	6.48 (0.73)	0.393
Secondary	26 (27.4)	38 (31.1)	0.553	0.67 (0.90)	0.7 (0.88)	0.850
Fragmentary	20 (21.1)	31 (25.4)	0.459	0.41 (0.64)	0.56 (0.77)	0.128
Shape						
Curved	80 (84.2)	98 (80.3)	0.459	2.67 (1.55)	2.44 (1.44)	0.258
Wavy	74 (77.9)	97 (79.5)	0.775	2.37 (1.32)	2.61 (1.46)	0.200
Straight	72 (75.8)	98 (80.3)	0.425	2.57 (1.53)	2.61 (1.51)	0.824
Cirvular	2 (2.1)	3 (2.5)	0.846	0.04 (0.25)	0.05 (0.25)	0.837
Nonspecific	0 (0)	1 (0.8)	0.382	0 (0)	0.01 (0.09)	0.379
Direction						
Forward	53 (55.8)	70 (57.4)	0.813	1.28 (1.50)	1.45 (1.67)	0.447
Straight	72 (75.8)	96 (78.7)	0.612	2.38 (1.57)	2.64 (1.82)	0.260
Backward	85 (89.5)	100 (82.0)	0.122	3.99 (2.15)	3.64 (2.34)	0.258
Unification						
Absent	95 (100)	122 (100)	-	6.72 (1.51)	6.93 (1.84)	0.368
Divergent	38 (40)	43 (35.2)	0.468	0.78 (0.79)	0.68 (0.9)	0.4
Convergent	13 (13.7)	11 (9)	0.273	0.16 (0.40)	0.12 (0.4)	0.52

[a]Z test; [b]Independent samples t test; *significant, p<0.05; **significant, p<0.01

characteristic of the population, such as the prevalence of curved and straight patterns in Bosnia and Herzegonina[15], or the wavy pattern in Jordan and Serbia.[27,28] However, in the assessed Lebanese sample, the three major rugae forms (curved, wavy and straight) were remarkably equally prevalent. This rare occurrence has only been recorded by a study of an Indian population in Central Kerala.[18] Yet, we join the majority of populations in the infrequent presence of unification (convergence or divergence), with the exception of Nigerians where mean numbers of diverging and converging rugae per individual were many folds greater.[21, 26]

Our data confirm earlier studies that illustrate the asymmetric nature of the palatal rugae, including rugae number, length, shape and/or direction.[17,27,29-31] The fact that rugae symmetry does not seem to be the norm in the average individual may be a major discriminant for the individual "finger print" nature of palatal rugae. Nonetheless, despite side-related differences in rugae form and direction, palatal rugae number appears to be

symmetric, a finding supported by some previous studies[19,32] but not others.[29,31] It must be emphasized that patients who presented with posterior crossbite were deliberately excluded from our sample to restrict inclusion to individuals representing the normal spectrum of transverse maxillary/palatal growth.

Unlike research on different populations that illustrates gender dimorphism in various traits, especially palatal rugae shapes and unification patterns,[4,12,13,22-24] none of the characteristics assessed in our sample exhibited any significant differences between males and females.

Table 5. Differences in palatal rugae characteristics between right and left side in females, according to Thomas and Kotze classification (n = 122)

	Incidence			Number per individual		
	Right n (%)	Left n (%)	p^a	Right Mean (SD)	Left Mean (SD)	p^b
Length						
Primary	122 (100.0)	122 (100.0)	-	3.21 (0.55)	3.26 (0.50)	0.469
Secondary	34 (27.9)	38 (31.1)	0.584	0.30 (0.49)	0.40 (0.68)	0.139
Fragmentary	31 (25.4)	23 (18.9)	0.222	0.31 (0.58)	0.25 (0.57)	0.391
Shape						
Curved	86 (70.5)	98 (80.3)	0.076	1.09 (0.97)	1.35 (0.96)	0.026*
Wavy	92 (75.4)	97 (79.5)	0.444	1.28 (1.00)	1.34 (0.96)	0.629
Straight	98 (80.3)	92 (75.4)	0.357	1.43 (1.03)	1.19 (1.01)	0.056
Cirvular	3 (2.5)	3 (2.5)	1.000	0.02 (0.16)	0.02 (0.16)	1
Nonspecific	0 (0.0)	1 (0.8)	0.322	0.00 (0.00)	0.01 (0.09)	0.319
Direction						
Forward	70 (57.4)	37 (30.3)	<0.001**	0.95 (1.06)	0.50 (0.95)	<0.001**
Straight	96 (78.7)	70 (57.4)	<0.001**	1.51 (1.12)	1.13 (1.26)	0.007**
Backward	84 (68.9)	100 (81.9)	0.018*	1.36 (1.33)	2.28 (1.59)	<0.001**
Unification						
Absent	121 (99.2)	122 (100.0)	0.322	3.42 (1.11)	3.51 (1.17)	0.460
Divergent	43 (35.2)	33 (27.0)	0.167	0.38 (0.55)	0.30 (0.53)	0.171
Convergent	3 (2.5)	11 (9.0)	0.029*	0.02 (0.16)	0.10 (0.33)	0.012*

[a]Z- test; [b]paired t test; *significant, p<0.05; **significant, p<0.01

Although more scarce, a few studies carried out in India[2], Bosnia and rzegovina[16], Serbia[28] and Jordan[27] have also noted lack of dimorphism, while one other study carried out in the

Mediterranean region did report gender differences.[12]

The above-delineated differences across populations suggest that findings may be specific to certain populations. The scarcity of research in the Mediterranean regions invites additional investigation. Despite the substantial size of our sample, further research shall help validate our findings, which represent a first step towards building a Lebanese database of palatal rugae morphology and a distinct component in the overall representation of the palatal rugae in Mediterranean populations.

CONCLUSIONS

1. Our data underscore the variability in palatal rugae morphology across different populations and within individuals and are a valuable addition to the scarce literature on palatal rugae morphology in Caucasian Mediterranean populations.
2. The prevalence of palatal rugae shapes did not differ between genders in the Lebanese population, a distinct finding

compared to other Mediterranean, African and Asian populations.

3. The comparisons between populations indicate the importance of generating norms specific to racial, ethnic,

or geographic groups, thus the importance of future investigation in larger samples and primary comparisons with other Mediterranean populations

Table 6. Differences in palatal rugae characteristics between males and females, according to Thomas and Kotze classification (n = 217)

	Incidence			Number per individual		
	Males (n = 95)	Females (n = 122)		Males (n = 95)	Females (n = 122)	
	n (%)	n (%)	p^a	Mean (SD)	Mean (SD)	p^b
Length						
Primary	95 (100.0)	122 (100.0)	-	6.57 (0.87)	6.48 (0.73)	0.393
Secondary	26 (27.4)	38 (31.1)	0.553	0.67 (0.90)	0.7 (0.88)	0.850
Fragmentary	20 (21.1)	31 (25.4)	0.459	0.41 (0.64)	0.56 (0.77)	0.128
Shape						
Curved	80 (84.2)	98 (80.3)	0.459	2.67 (1.55)	2.44 (1.44)	0.258
Wavy	74 (77.9)	97 (79.5)	0.775	2.37 (1.32)	2.61 (1.46)	0.200
Straight	72 (75.8)	98 (80.3)	0.425	2.57 (1.53)	2.61 (1.51)	0.824
Cirvular	2 (2.1)	3 (2.5)	0.846	0.04 (0.25)	0.05 (0.25)	0.837
Nonspecific	0 (0)	1 (0.8)	0.382	0 (0)	0.01 (0.09)	0.379
Direction						
Forward	53 (55.8)	70 (57.4)	0.813	1.28 (1.50)	1.45 (1.67)	0.447
Straight	72 (75.8)	96 (78.7)	0.612	2.38 (1.57)	2.64 (1.82)	0.260
Backward	85 (89.5)	100 (82.0)	0.122	3.99 (2.15)	3.64 (2.34)	0.258
Unification						
Absent	95 (100)	122 (100)	-	6.72 (1.51)	6.93 (1.84)	0.368
Divergent	38 (40)	43 (35.2)	0.468	0.78 (0.79)	0.68 (0.9)	0.4
Convergent	13 (13.7)	11 (9)	0.273	0.16 (0.40)	0.12 (0.4)	0.52

[a]Z test; [b]Independent samples t test; *significant, p<0.05; **significant, p<0.01

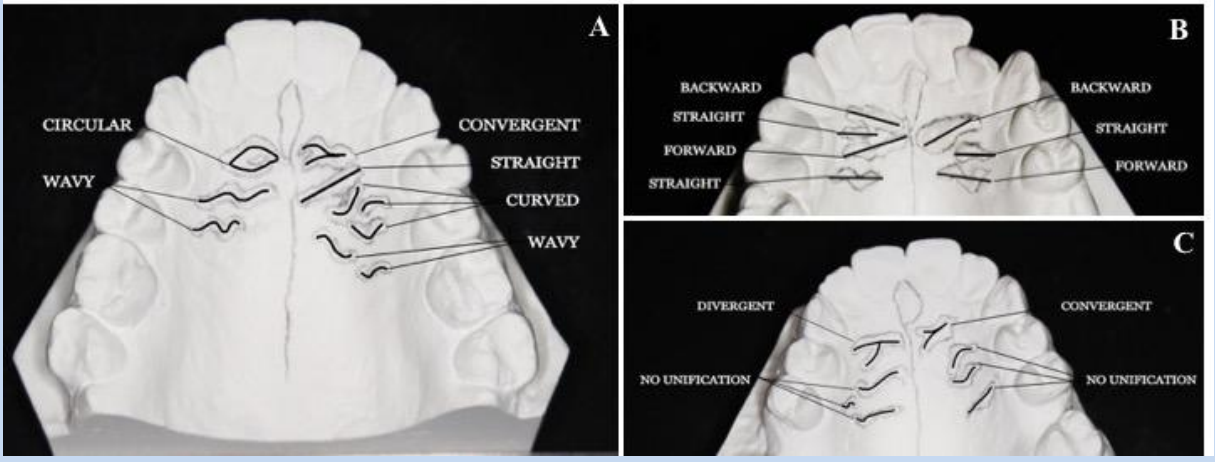

Fig. 1: Classification of palatal rugae based on shape (A), direction (B) and unification (C)

Table 7. Comparison of selected studies assessing palatal rugae morphology in various populations

Study (year)	Population (n)	Total/Primary/ secondary/ fragmentary (right+left) *(mean number)*	Curved/wavy /straight *(% or mean number)*	No unification/ diverging/converging *(% or mean number)*
Alani et al. (2016)[18]	Indian (82)	*/*/*/*	31.7/31.7/34.2	*/*/*
Azab et al. (2015)[12]	Egyptian (108)	*/7.6/1.3/1.0	Means: 1.9/3.2/2.2	Means: */0.6/1.5
Babu et al. (2013)[25]	Indian (100)	M: */7.5/2.8/1.9 F: */6.9/3.4/2.6	Means 1.6/4.8/3.9 Means: 1.5/4.7/3.8	*/*/*
Byatnal et al. (2014)[33]	Indian (100)	*/*/*/*	% M: 12/74/12.8 % F: 12.4/72.4/14	Unification present in: M: 1.2% F: 1.2%
Chopra et al. (2013)[13]	Indian (100)	M: */5.6/2.5/* F: */5.4/2.6/*	Means M: 2.2/2.7/1.0 Means F: 3.2/2.1/1.0	Means M: */0.4/0.9 Means F: */0.7/0.5
Dawasaz & Dinkar (2003)[34]	Indian (120)	11.3/*/*/*	%: 12.6/46.0/3.0	%: 97.6/*/*
Elamin et al. (2015)[23]	Sudan (300)	M: 11.2/8.2/1.8/1.9 F: 11.5/8.6/1.9/1.0	Means M: 1.4/4.6/2.8 Means F: 1.4/ 5.6/2.4	*/*/*
Fahmi et al. (2001)[22]	Saudi Arabia (120)	M: 7.3/3.7/1.3/* F: 7.2/3.6/1.6/*	% M: 26.1/45.4/12.0 % F: 24.0/43.7/14.1	% M: 89.6/1.8/8.6 % F: 83.7/1.2/15.1
Hermosilla et al. (2009)[35]	Chilean (120)	*/*/*/*	%: 27.0/43.0/14.9	*/*/*
Ibeachu et al. (2014)[26]	Nigerian, Igbo and Ikwerre (140)	*/*/*/*	% Males: Ikwerre: 45.1/35.6/9.9 Igbo: 27.9/51.1/6.1 % Females: Ikweree: 34.3/40.5/11.8 Igbo: 26.1/59.9/4.8	Mean M: 1: */3.9/2.1 2: */5.1/3.2 Mean F: 1: */6.2/1.9 2: */2.4/1.6
Kapali et al. (1997)[21]	Australian Caucasian (220) and Australian Aboriginal (110)	Caucasian: M: 8.6/*/*/* F: 8.6/*/*/* Aboriginal: M: 10/*/*/* F: 9.8/*/*/*	Caucasian: %: 23.2/55.8/3.6 Aboriginal: %: 25.8/40.6/15.2	Unification present in: Caucasian: 15.6% Aboriginal: 13.9%
Lysell et al. (1955)[7]	Central Europeans (100) and Swedes (100)	Central Europeans: M: 8.5/*/*/* F: 8.7/*/*/* Swedes: M: 8.9/*/*/* F: 8.2/*/*/*	Swedes: M and F: Approx. 2/3 are curved/wavy	Swedes: Means M: */0.1/0.2 Means F: */0.1/0.2
Madhankumar et al. (2013)[24]	Indian (135)	M: 9.5/7.7/1.8/* F: 10.2/8.2/2.0/*	Means M: 2.3/2.0/4.8 Means F: 1.7/ 2.0/5.1	*/*/*
Manjunath et al. (2012)[30]	Indian (63)	M: 8.2/*/*/* F: 8.4/*/*/*	Means M: 1.8/5.7/1.2 Means F: 1.9/5.3/1.8	*/*/*
Mathew et al. (2016)[4]	Indian (50)	M: 10.9/7.6/2.4/0.8 F: 11.2/8.3/2.0/1.0	Means M: 5.0/2.8/2.7 Means F: 5.2/1.6/3.9	*/*/*
Muhasilovic et al. (2016)[16]	Bosnia and Herzegovina (250)	M: 5.8/5.3/0.5/0.02 F: 5.9/5.1/0.7/0.02	Means M: 1.5/3.2/0.8 Means F: 1.5/3.0/1.0	*/*/*
Shetty & Premalatha (2011)[36]	Indian (100)	*/*/*/*	%: 20.8/59.6/16.4	*/*/*
Present study	Lebanese (217)	7.7/6.5/0.7/1.1	Means: 2.5/2.5/2.6 %: 33.1/32.6/33.7	Means: 6.8/0.7/0.1 %: 88.8/9.4/1.8

Notes. M: males; F: females.
* Morphological feature not assessed/reported by referenced study

REFERENCES

1. *Muthusubramanian M, Limson K, Julian R. Analysis of rugae in burn victims and cadavers to simulate rugae identification in cases of incineration and decomposition. J Forensic Odontostomatol 2005;23(1):26-9.*
2. *Chandra S, Pandey V, Wasti A, Mangat SS, Bhagat JK, Singh R. Analysis of rugae pattern in Ranchi and Patna*
3. *Wu X-P, Han J-N, Fen P, Wang Y-J, Bing L, Wu X, Han J, Fen P, Wang Y, Bing L. Application of palatal rugae morphology in forensic identification. Int J Morphol 2016;34(2):510-3.*
4. *Mathew SA, Kasim K, Mrudula K, Jayashekeran. Establishing identity using cheiloscopy and palatoscopy. Sch J Dent Sci 2016;3(3):74-80.*
5. *Bhullar A, Kaur RP, Kamat MS. Palatal rugea–an aid in clinical dentistry. J Forensic Res 2011;2(3):1-4.*
6. *Santos C, Caldas IM. Palatal rugae pattern in a Portuguese population: a preliminary analysis. J For Sci 2012;57(3):786-8.*
7. *Lysell L. Plicae palatinae transversae and papilla incisiva in man; a morphologic and genetic study. Acta Odontologica Scandinavica 1955;13(Suppl. 18):5-137.*
8. *Thomas C, Kotze T. The palatal rugae pattern in six southern African populations, interracial differences. J Dent Assoc S Afr 1983;38:166–72.*
9. *Shanmugam S, Anuthama K, Shaikh H, Murali K, Suresan V, Nisharudeen K, Devi SPB, Rajasundaram P. Palatal rugae in population differentiation between South and North Indians: A discriminant function analysis. J Forensic Dent Sci 2012;4(2):75-9.*
10. *Shetty S, Kalia S, Patil K, Mahima V. Palatal rugae pattern in Mysorean and Tibetan population. Indian J Dent Res 2005;16:51–5.*
11. *Suhartono A, Syafitri K, Puspita A, Soedarsono N, Gultom F, Widodo P, Luthfi M, Auerkari E. Palatal rugae patterning in a modern Indonesian population. Int J Leg Med 2016;130(3):881-7.*
12. *Azab SM, Magdy R, Sharaf El Deen MA. Patterns of palatal rugae among adult Egyptian population. Egypt J For Sci 2016, 6(2):78–83.*
13. *Chopra A, Rao N, Gupta N, Vashisth S. Palatal rugae and arch length: A tool in gender determination. Univ Res J Dent 2013;3(2):54-9.*
14. *Fawzi M, Eldomiaty M, Desouky M, Algaidi S. Evaluation of the role of palatal rugae application as a tool for sex identification in the Saudi population. WIMJ Open 2016,3(1):28-31.*
15. *Gondivkar SM, Patel S, Gadbail AR, Gaikwad RN, Chole R, Parikh RV. Morphological study of the palatal rugae in western Indian population. J For Leg Med 2011;18(7):310-2.*
16. *Muhasilovic S, Hadziabdic N, Galic I, Vodanovic M. Analysis of palatal rugae in males and females of an average age of 35 in a population from Bosnia and Herzegovina (Sarajevo Canton). J For Leg Med 2016;39:147-50.*
17. *Ahmed AA, Hamid A. Morphological study of palatal rugae in a Sudanese population. Int J Dent 2015;1-8.*
18. *Alani MM, Thomas SA, Mathew S, Arakkal LJ, Thomas W, Reba P. Analysis of rugae patterns and arch length in a Central Kerala population: an original research. J Int Oral Health 2016;8(1):129-31.*
19. *Eboh DE. Palatal rugae patterns of urhobos in abraka, South-Southern Nigeria. Int J Morphol 2012;30(2):709-13.*
20. *Thomas C, Kotze T. The palatal ruga pattern: a new classification. J Dent Assoc South Afr 1983;38(3):153-7.*
21. *Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian Aborigines and Caucasians. Aust Dent J 1997;42(2):129-33.*
22. *Fahmi FM, Al-Shamrani SM, Talic YF. Rugae pattern in a Saudi population sample of males and females. Saudi Dent J 2001;13(2):92-5.*
23. *ELamin EI, Reddy NR, Ali EO. Palatal rugae: systematic analysis of its shape and dimensions in Sudanese population. Int J Dental Clin 2015;7(1).*
24. *Madhankumar S, Natarajan S, Maheswari U, Anand V, Padmanabhan T, Fathima B. Palatal rugae pattern for gender identification among selected student population in Chennai, India. J Sci Res Rep 2013;2(2):491-6.*
25. *Babu GS, Bharath TS, Kumar NG. Characteristics of palatal rugae patterns in west Godavari population of India. J Clin Diag Res 2013;7(10):2356-9.*
26. *Ibeachu P, Didia B, Arigbede A. A comparative study of palatal rugae patterns among igbo and ikwerre ethnic groups of Nigeria: A University of Port Harcourt Study. Anat Res Int 2014;1-8.*
27. *Mustafa AG, Allouh M, Tarawneh I, Alrbata R. Morphometric analysis of palatal rugae among Jordanians: further evidence of worldwide palatal rugae individuality. Aust J For Sci 2014;46(1):53-63.*
28. *Filipović G, Janošević M, Janošević P, Radojičić J, Ajduković Z, Tričković-Janjić O. Palatal rugae patterns in the Serbian population. Arch Biol Sci 2014;66(3):1131-4.*
29. *Bing L, Wu X-P, Feng Y, Wang Y-J, Liu H-C, Bing L, Wu X, Feng Y, Wang Y, Liu H. Palatal rugae for the construction of forensic identification. Int J Morphol 2014;32(2):546-50.*
30. *Manjunath S, Bakkannavar SM, Kumar P, Bhat VJ, Prabhu N, Kamath A, Raghavendra Babu Y. Palatal rugae patterns among the Indians at Manipal, India. J Pharm Biomed Sci 2012;20(20):1-5.*
31. *Indira A, Gupta M, David MP. Palatal rugae patterns for establishing individuality. J For Dent Sci 2012;4(1):2-5.*
32. *Bhateja S, Arora G. Analysis of palatal rugae for human identification in Indian (Mathura) population. Ind J Dent Sci 2013;5(3):24-7.*
33. *Byatnal A, Byatnal A, Kiran AR, Samata Y, Guruprasad Y, Telagi N. Palatoscopy: An adjunct to forensic odontology: A comparative study among five different populations of India. J Nat Sci Biol Med 2014;5(1):52-5.*

34. *Dawasaz AA, Dinkar AD. Rugoscopy: predominant pattern, uniqueness, and stability assessment in the Indian goan population. J For Sci 2013;58(6):1621-7.*
35. *Hermosilla V, San Pedro V, Cantin L, Suazo G. Palatal rugae: Systematic analysis of its shape and dimensions for use in human identification. Int J Morphol 2009;27(3):819-25.*
36. *Shetty M, Premalatha K. Study of palatal rugae pattern among the student population in Mangalore. J Indian Acad Forensic Med 2011;33(2):112-5.*

*****